CTA

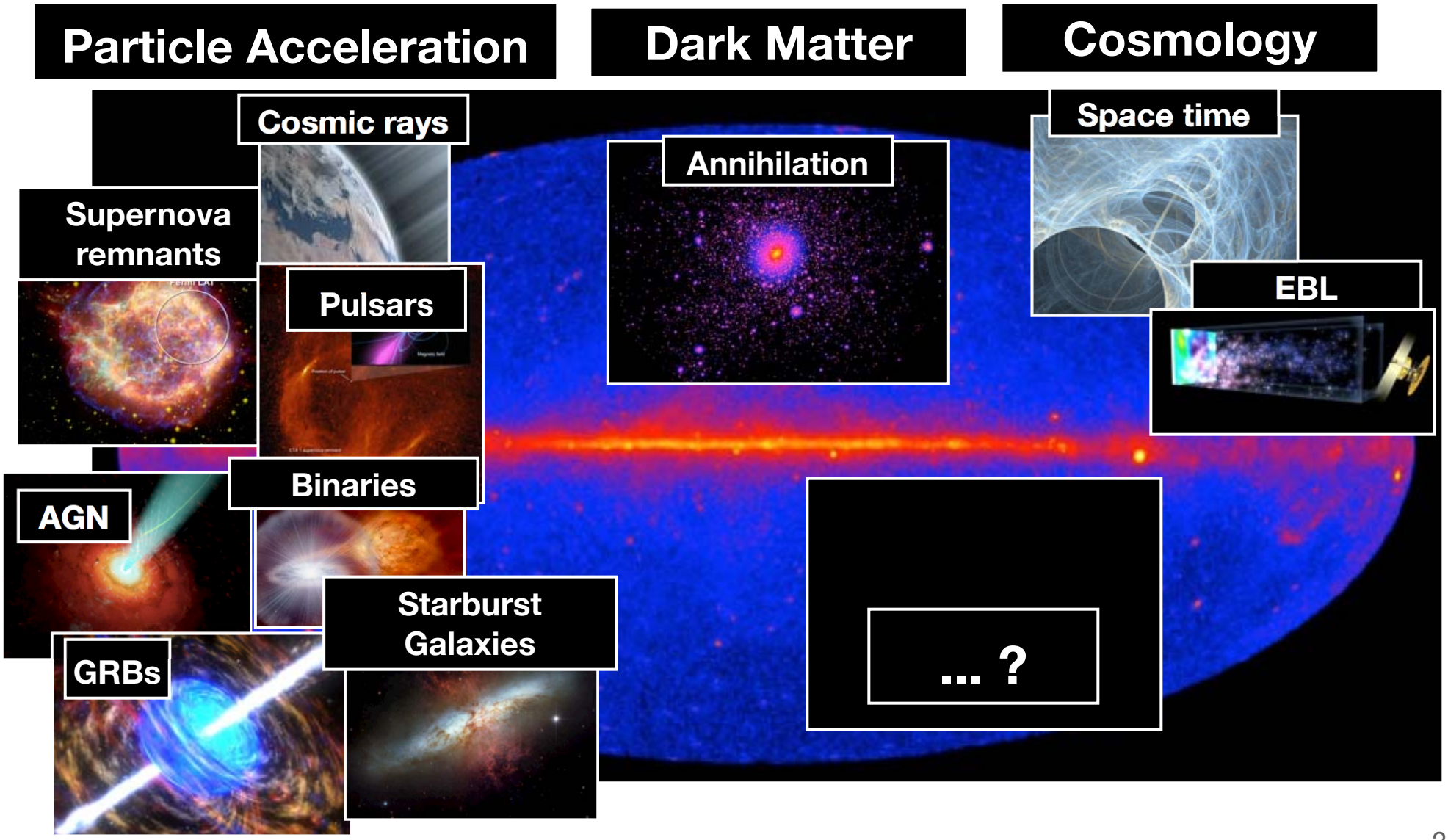
The Cherenkov Telescope Array

(Stefan Funk for the CTA Consortium)

KIPAC KAVLI INSTITUTE FOR PARTICLE ASTROPHYSICS AND COSMOLOGY

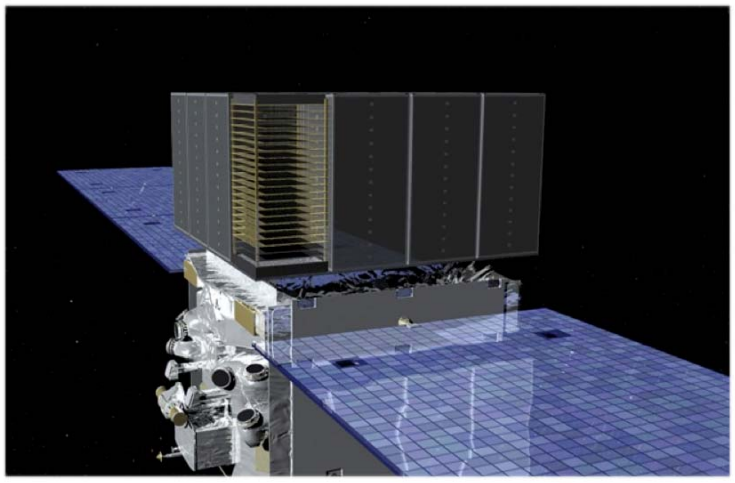
cta
cherenkov telescope array

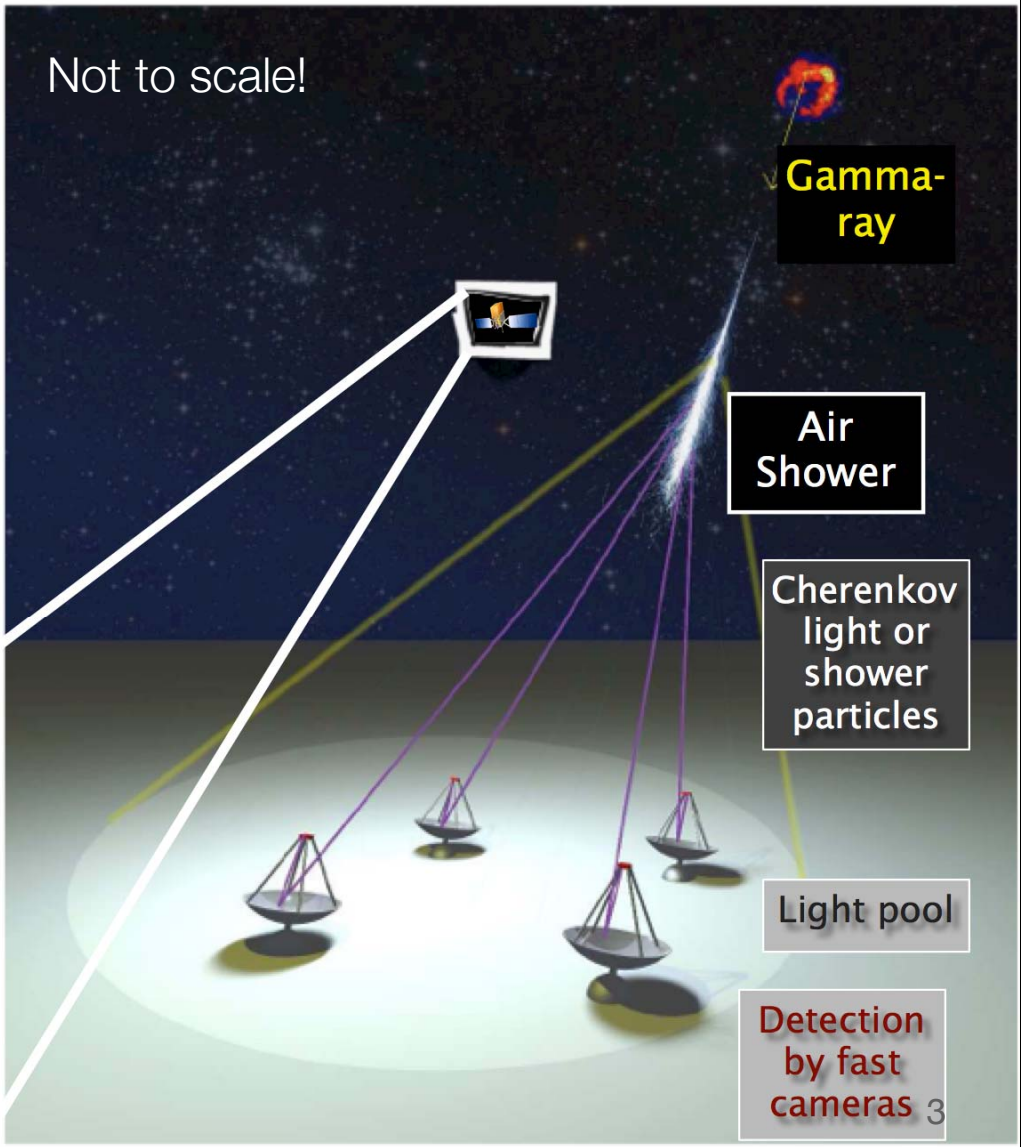
Gamma-ray astrophysics



Detection of γ-rays

- Put instrument outside of the atmosphere (Fermi-LAT)
  - Ideal for lower-energy ($dN/dE \sim E^{-\alpha}$)
- Use atmosphere as part of the detector
  - Access to high-energy gamma rays



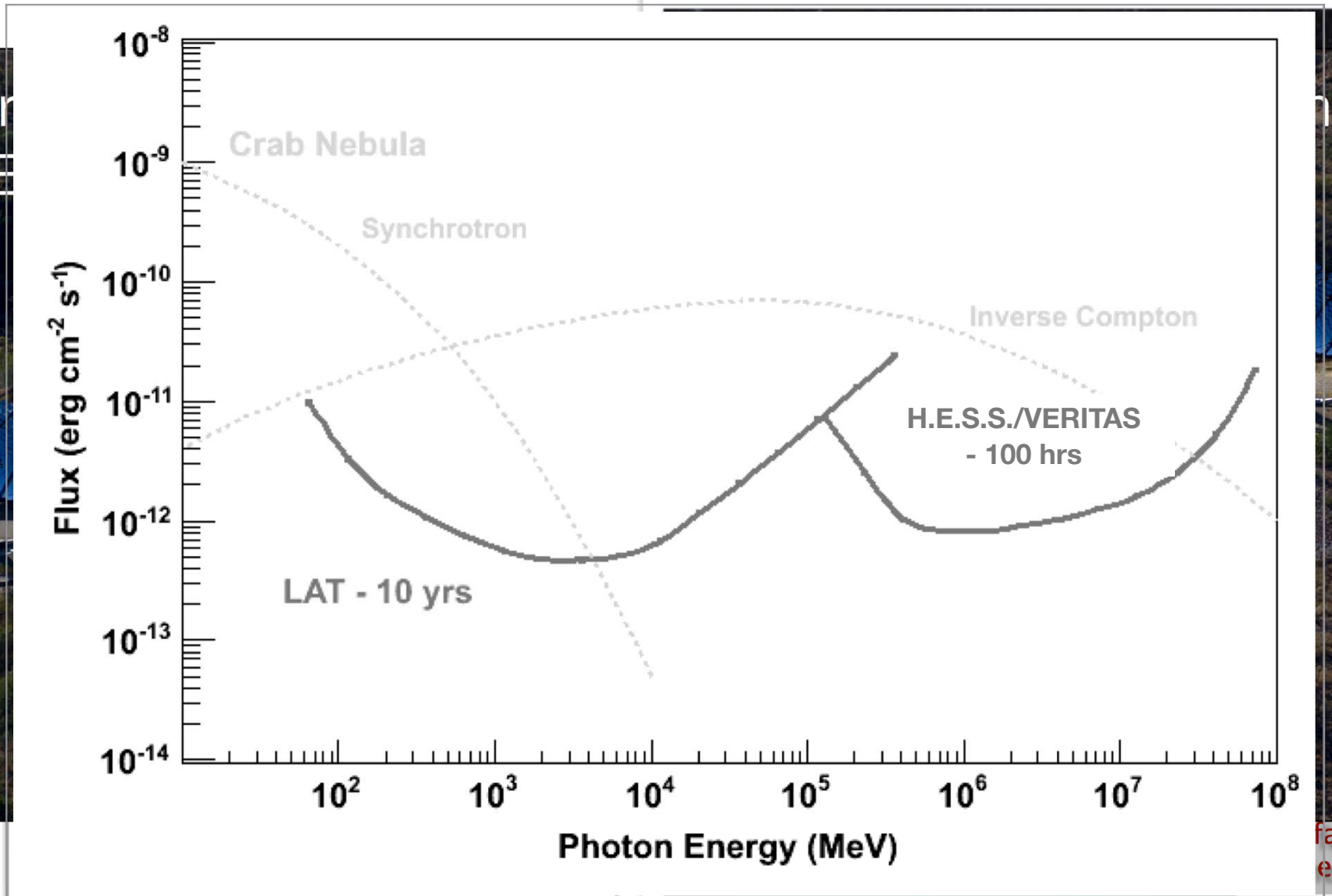


Detection of γ-rays

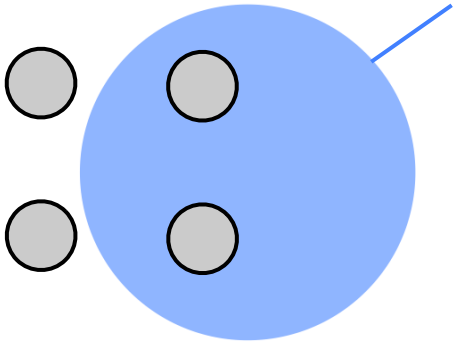
- Very Energetic Radiation Imaging Telescope Array System (VERITAS)

by fast cameras

Detection of γ-rays

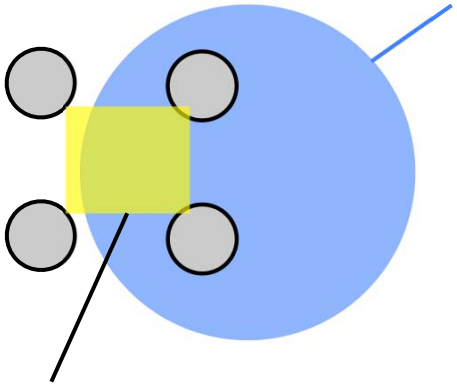


From current arrays to CTA



Light pool radius
R ≈100-150 m
≈ typical telescope spacing

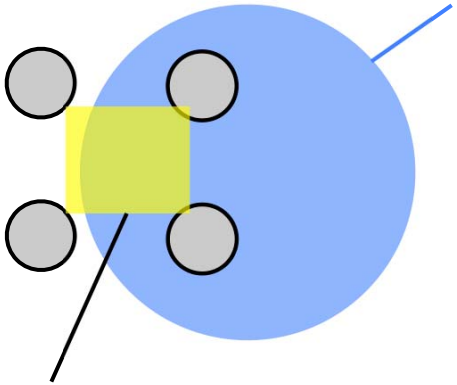
From current arrays to CTA



Light pool radius
R ≈100-150 m
≈ typical telescope spacing

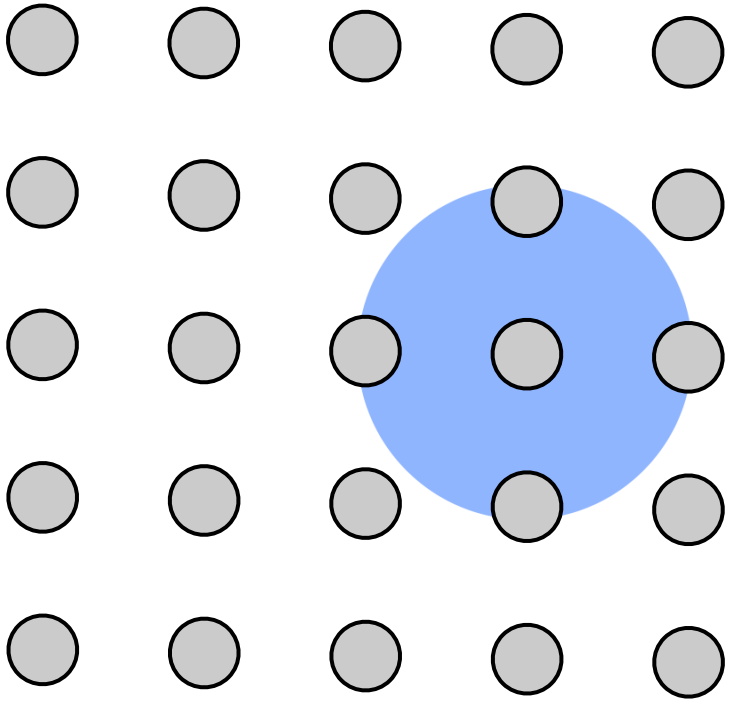
Sweet spot for
best triggering
and reconstruction:
Most shower cores miss it!

From current arrays to CTA

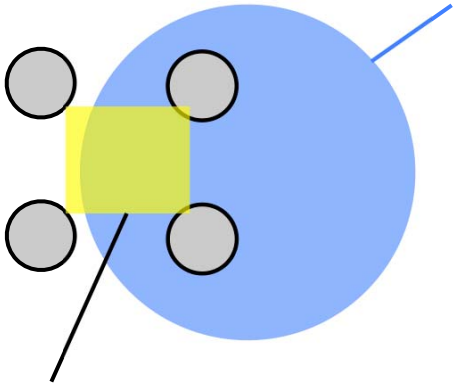


Light pool radius
R ≈100-150 m
≈ typical telescope spacing

Sweet spot for
best triggering
and reconstruction:
Most shower cores miss it!

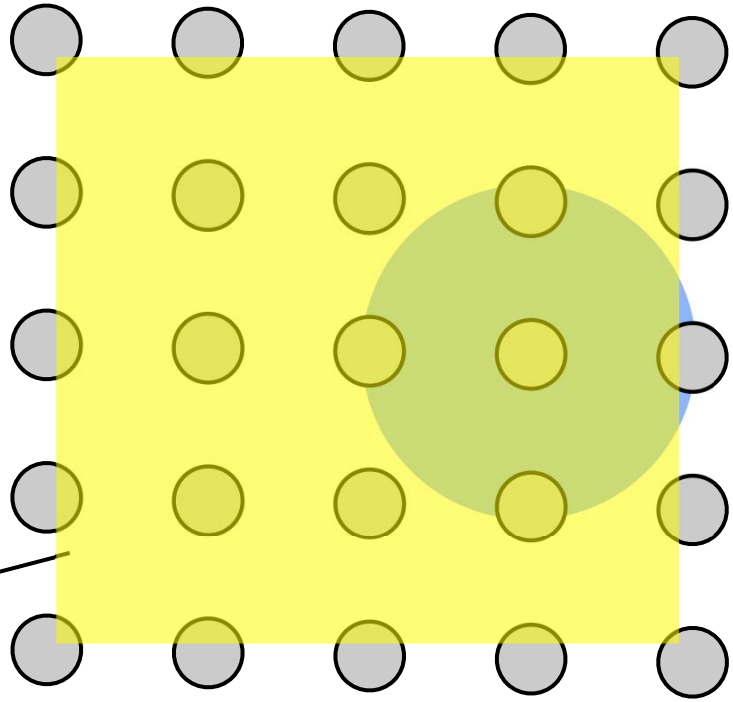


From current arrays to CTA



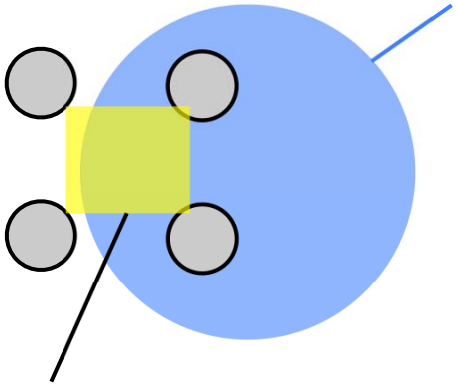
Light pool radius
R ≈100-150 m
≈ typical telescope spacing

Sweet spot for
best triggering
and reconstruction:
Most shower cores miss it!



Large detection area
More images per shower
Lower trigger threshold

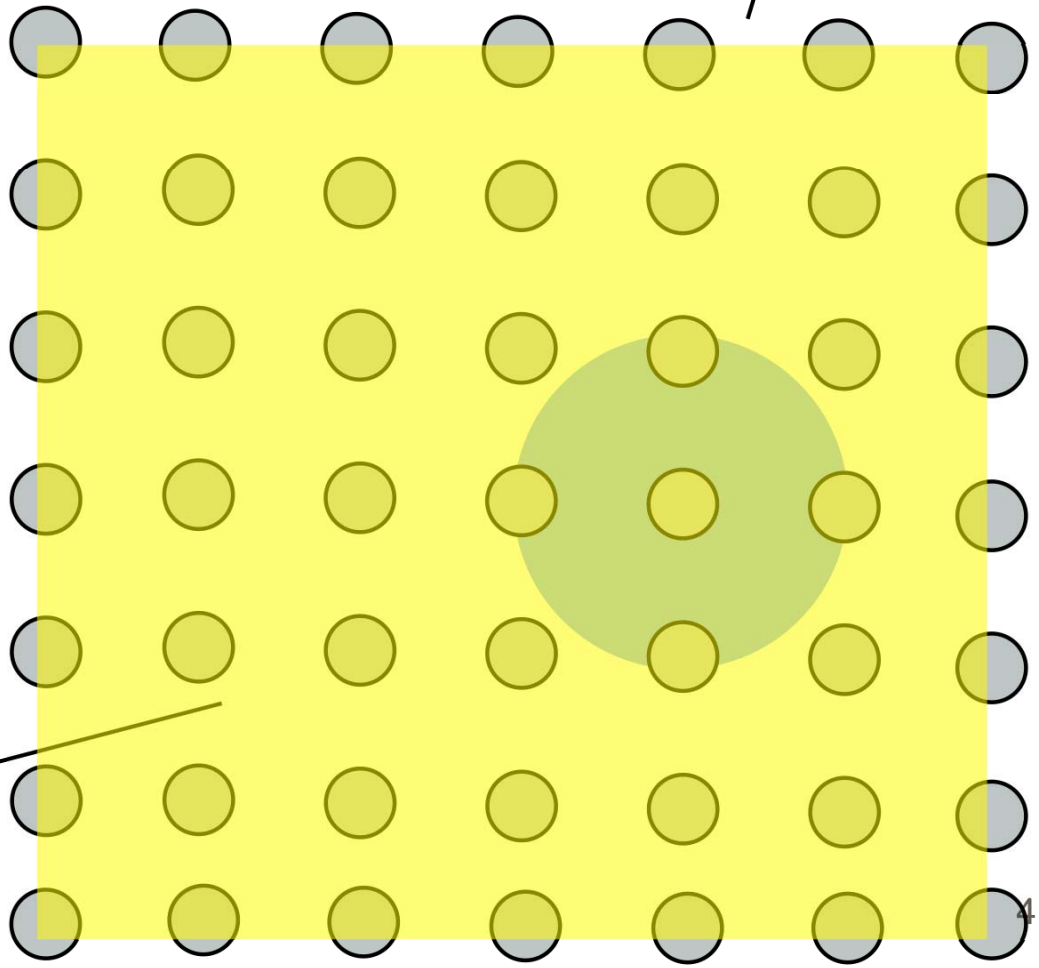
From current arrays to CTA



Sweet spot for
best triggering
and reconstruction:
Most shower cores miss it!

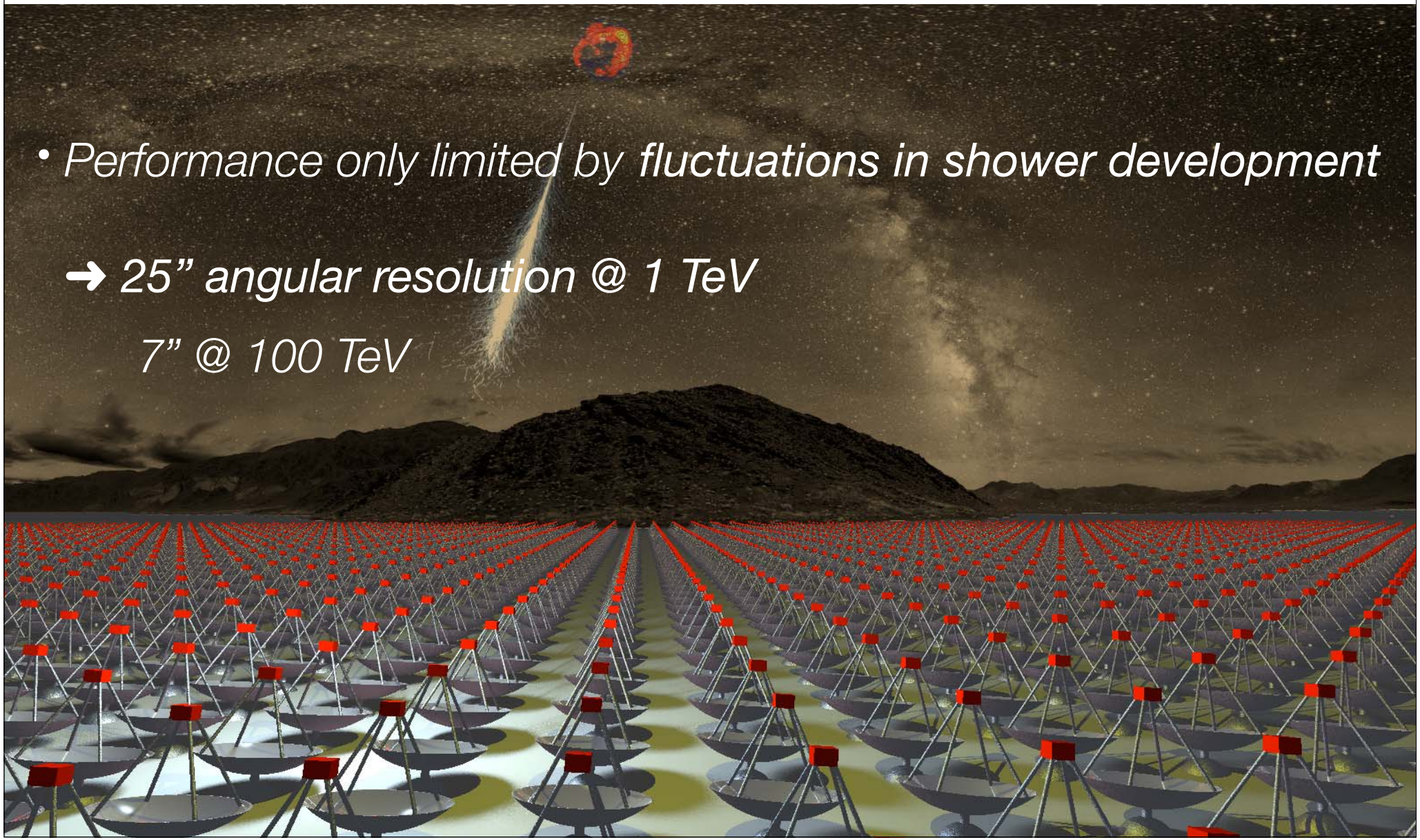
Light pool radius
R ≈100-150 m
≈ typical telescope spacing

With US telescopes



Large detection area
More images per shower
Lower trigger threshold

What one would like to have ...

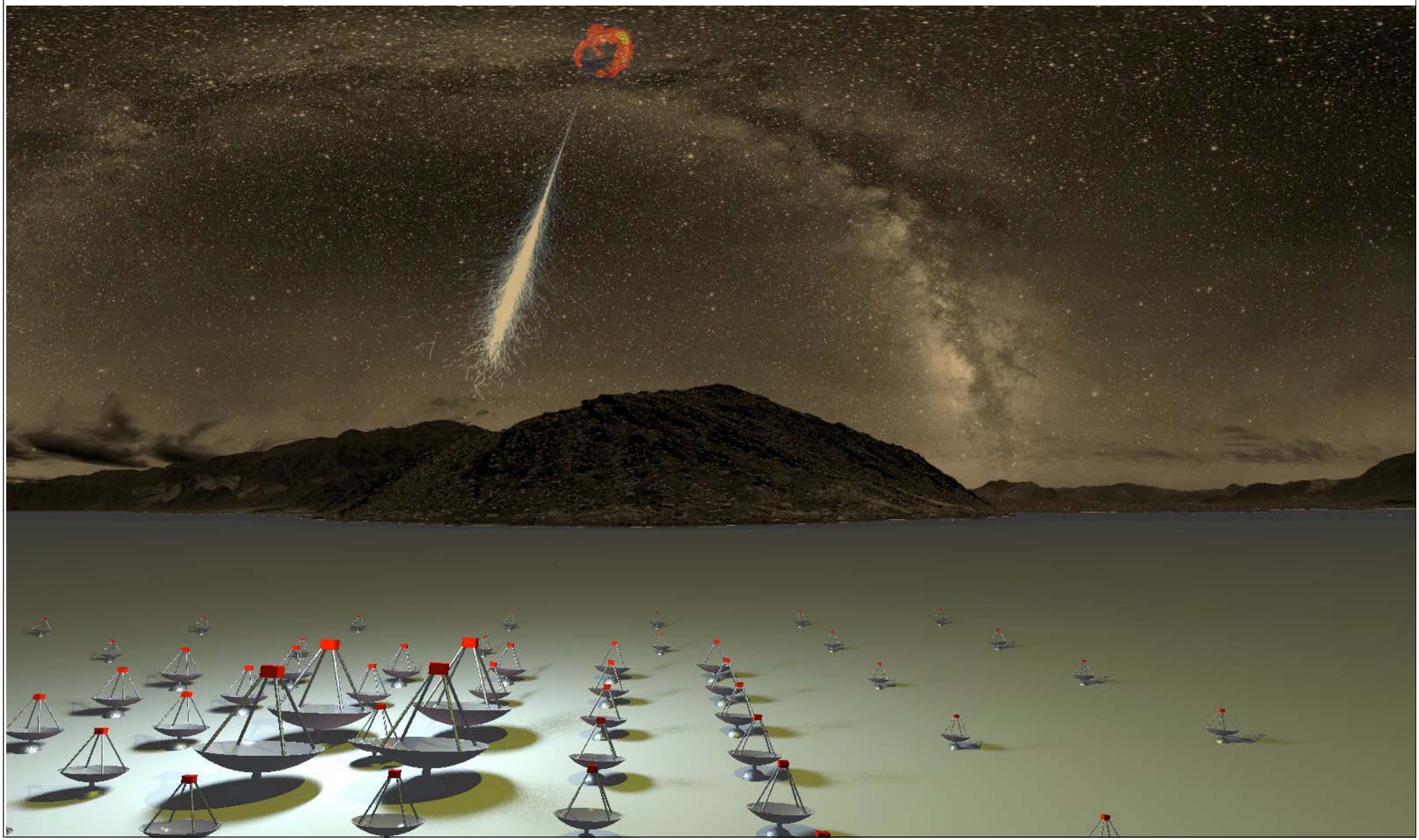


- *Performance only limited by **fluctuations in shower development***

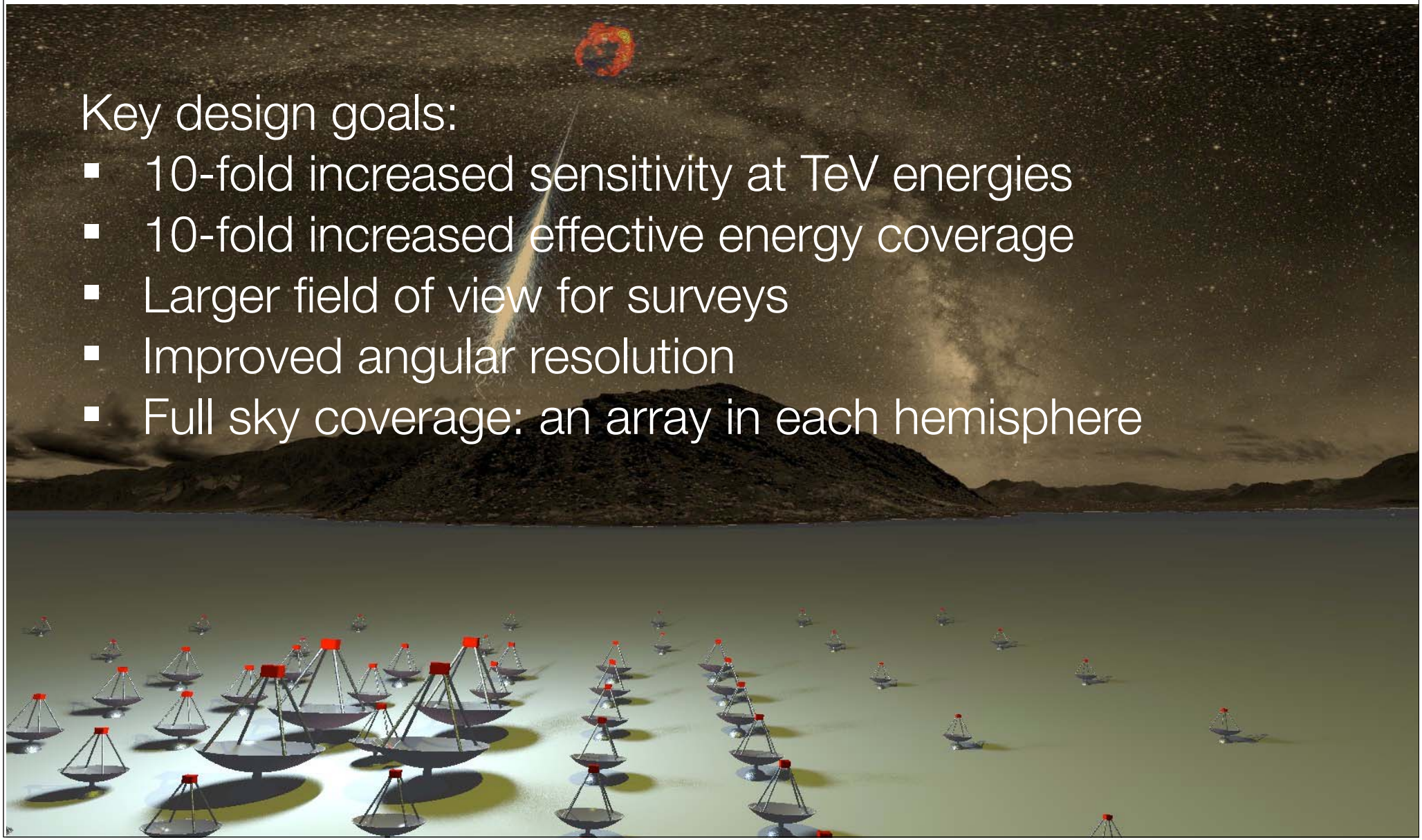
➜ *25” angular resolution @ 1 TeV*

7” @ 100 TeV

What one can (hopefully) afford ...



What one can (hopefully) afford ...



Key design goals:

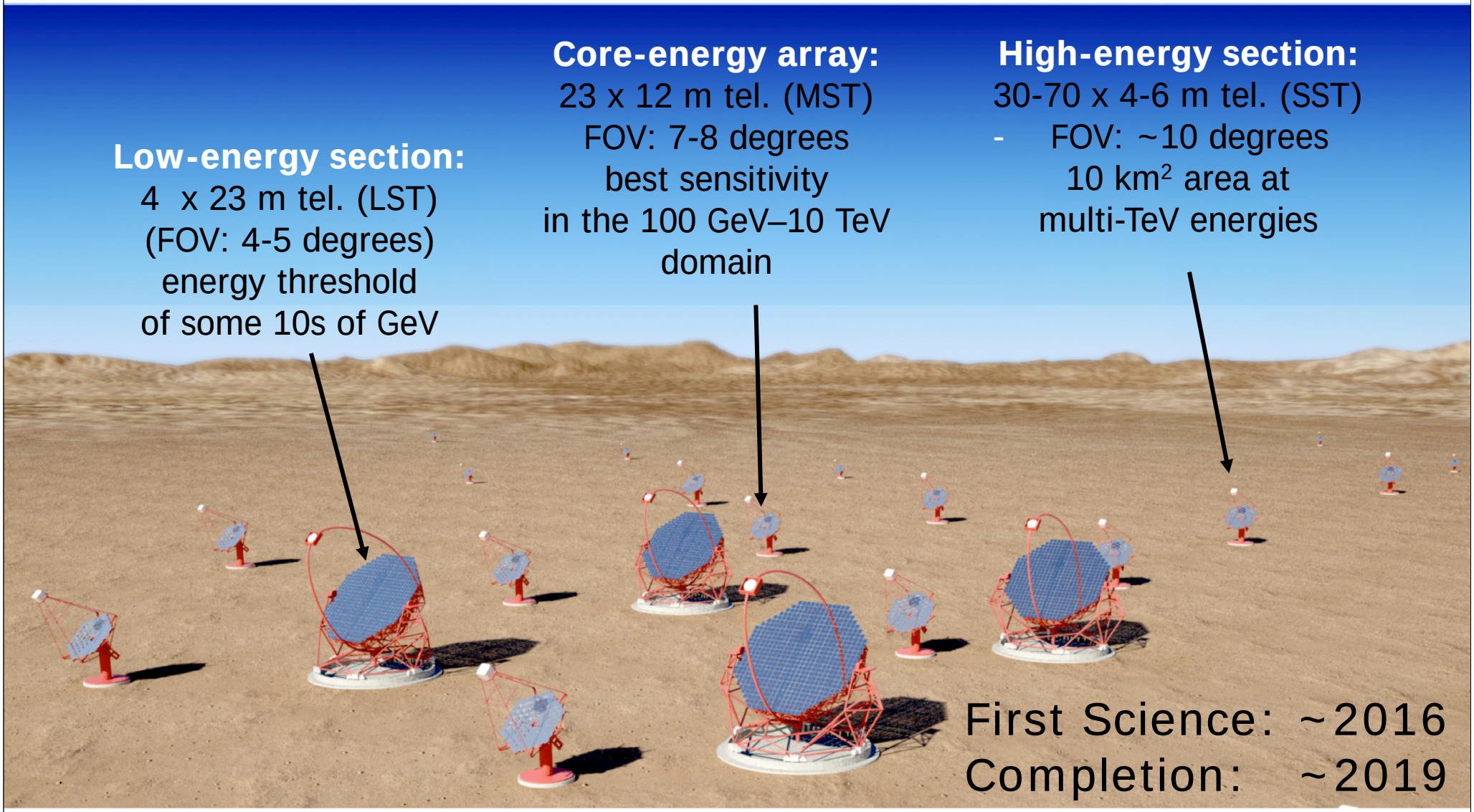
- 10-fold increased sensitivity at TeV energies
- 10-fold increased effective energy coverage
- Larger field of view for surveys
- Improved angular resolution
- Full sky coverage: an array in each hemisphere

The baseline ...

Low-energy section:
4 x 23 m tel. (LST)
(FOV: 4-5 degrees)
energy threshold
of some 10s of GeV

Core-energy array:
23 x 12 m tel. (MST)
FOV: 7-8 degrees
best sensitivity
in the 100 GeV–10 TeV
domain

High-energy section:
30-70 x 4-6 m tel. (SST)
- FOV: ~10 degrees
10 km^2 area at
multi-TeV energies



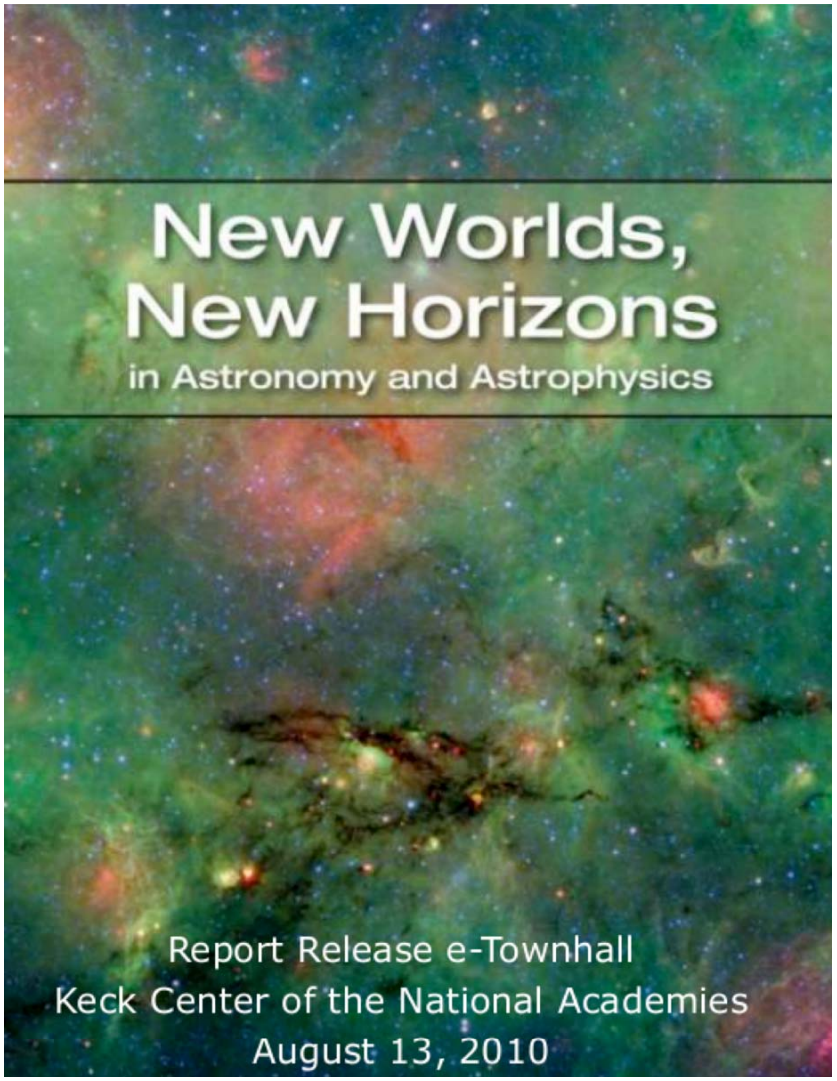
First Science: ~2016
Completion: ~2019

Recommended by relevant roadmaps

Report of the HEPAP Particle Astrophysics Scientific Assessment Group (PASAG)

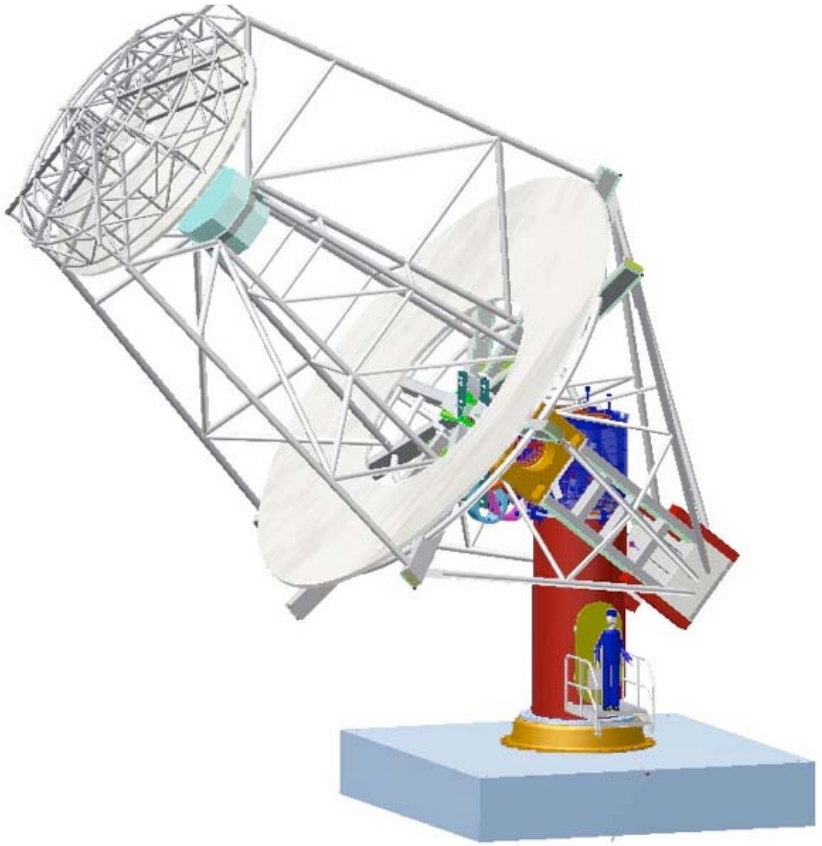
23 October 2009

U.S. Department of Energy and the National Science Foundation

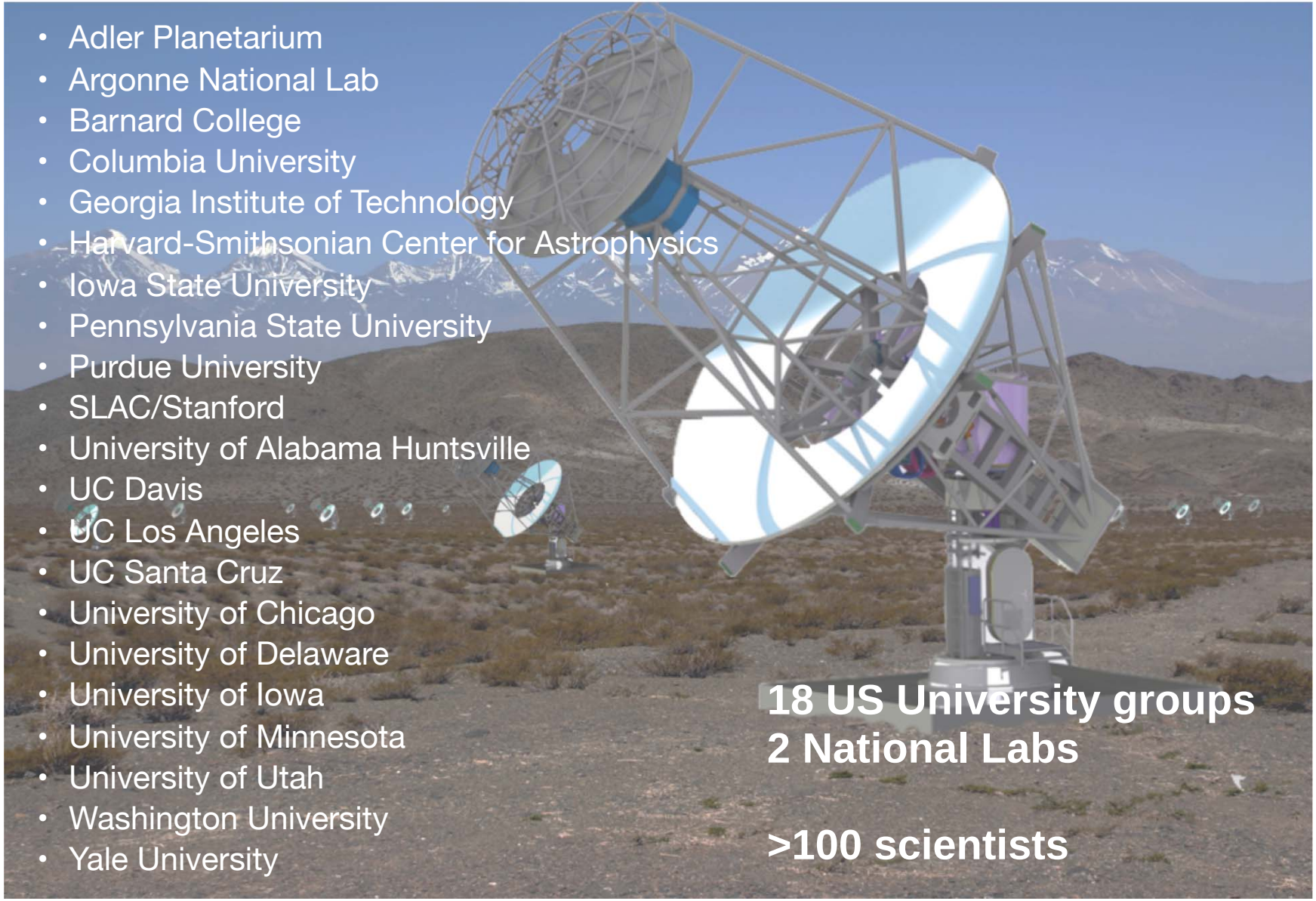


The US contribution

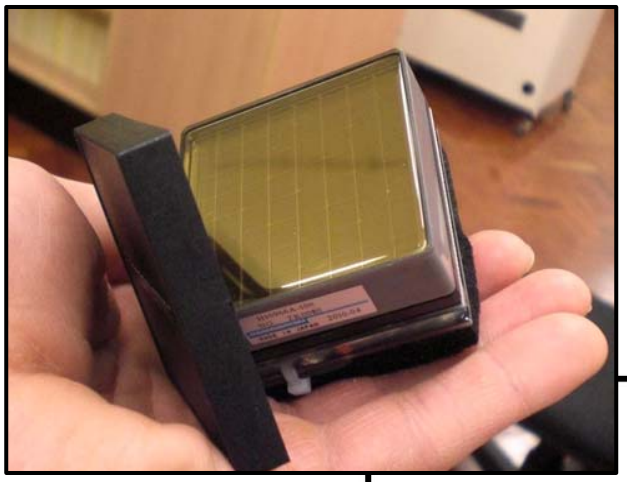
- Focus on the mid-sized telescopes
  - The sweet-spot of the technique
- Start from suggested contribution from Astro2010
  - Double the number of mid-sized telescopes over baseline array
  - “Enhanced” telescope design
  - Secondary mirror allows for very small optical PSF across the whole field of view



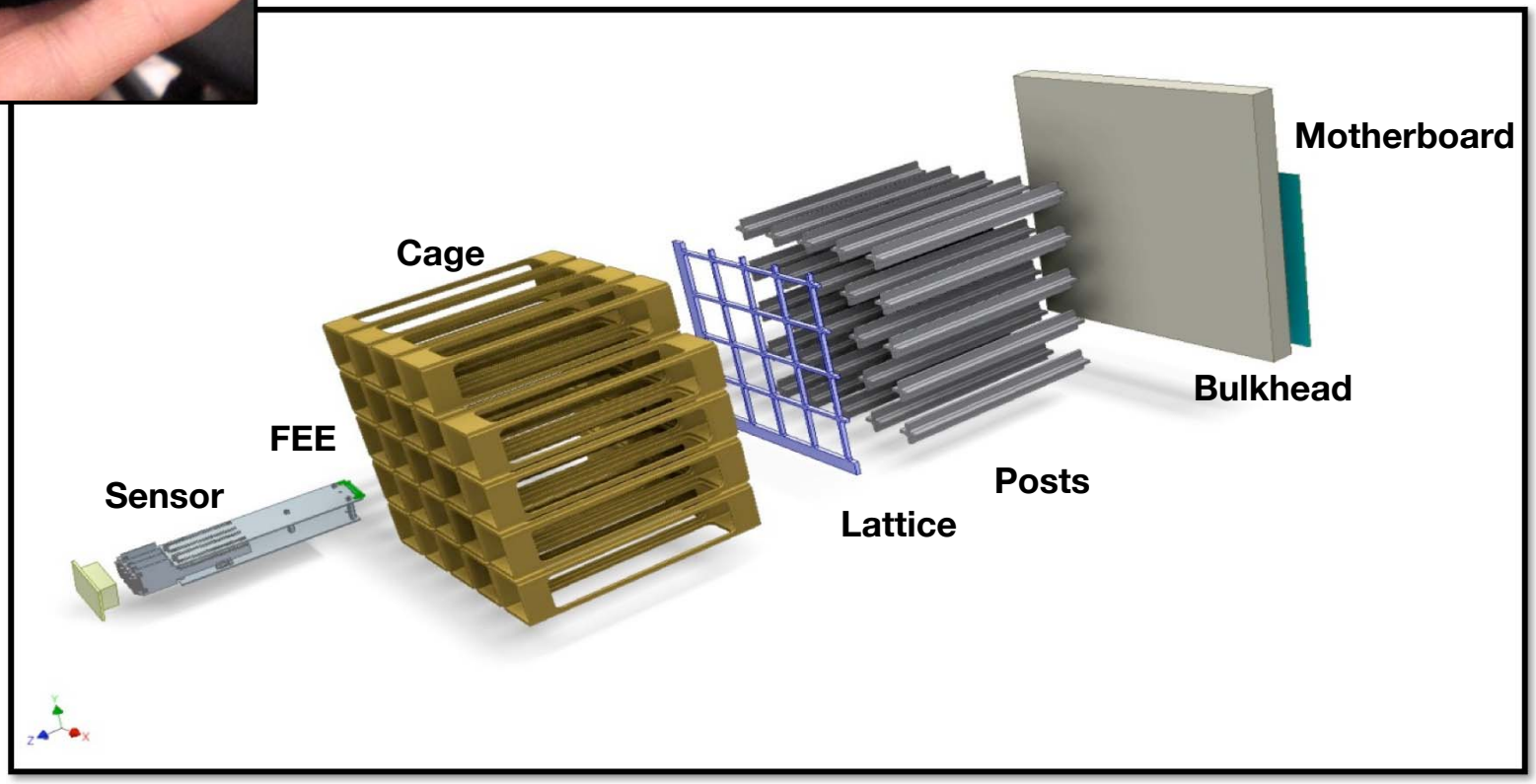
The US groups

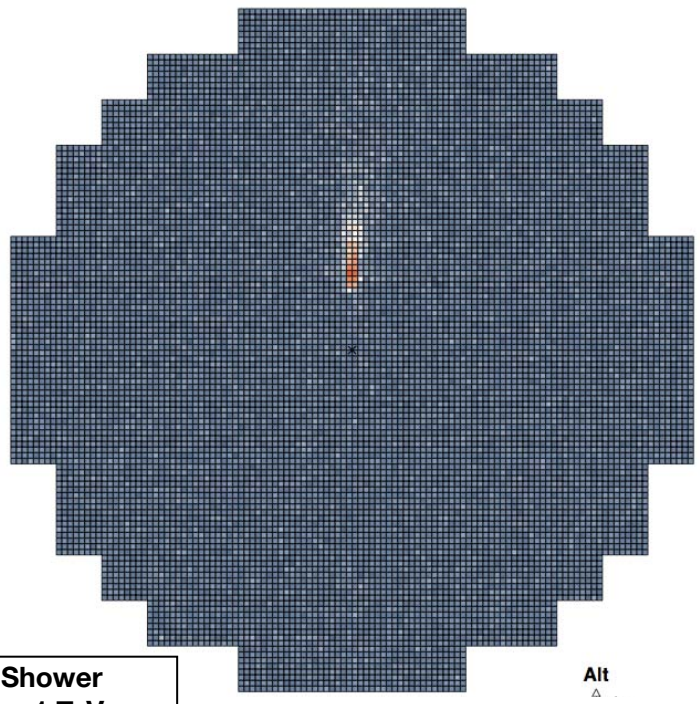


Highly pixelized imaging of shower

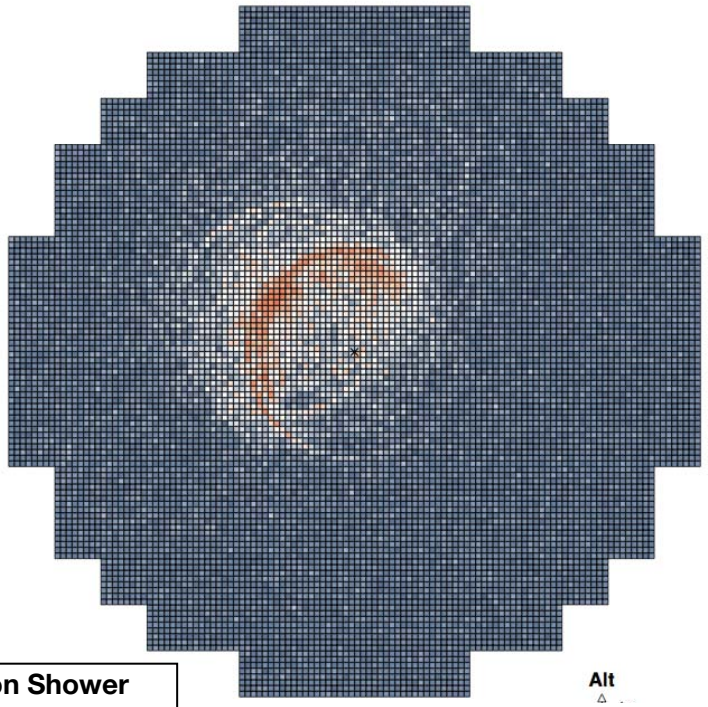


- Compare e.g. US camera to HESS-II camera:
  - Number of pixels: times 4 (~11500 vs ~2900)
  - Field of view: ~700% (solid angle)
  - Linear Size: ~40%
  - Mass: ~10%
  - Power consumption: ~25%



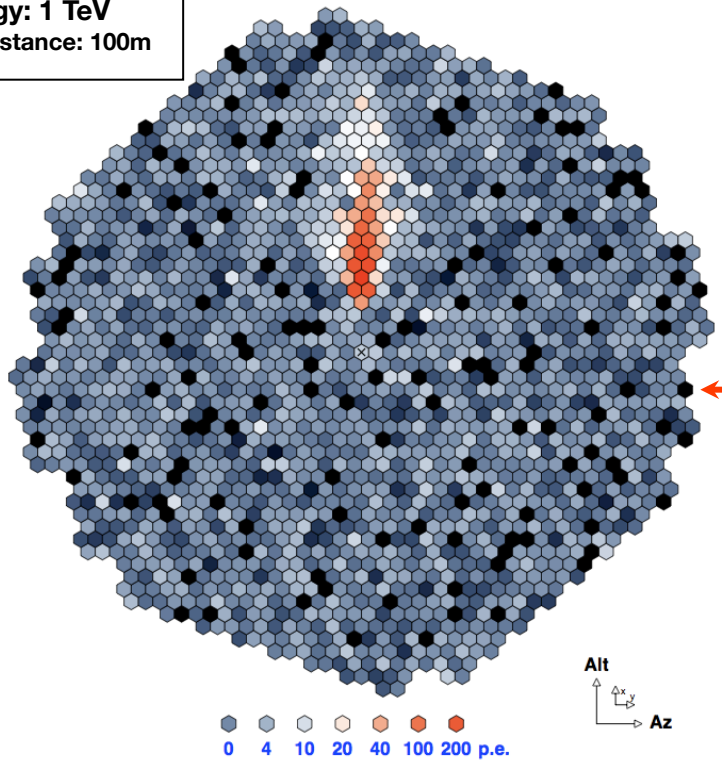


Dual Mirror Telescope

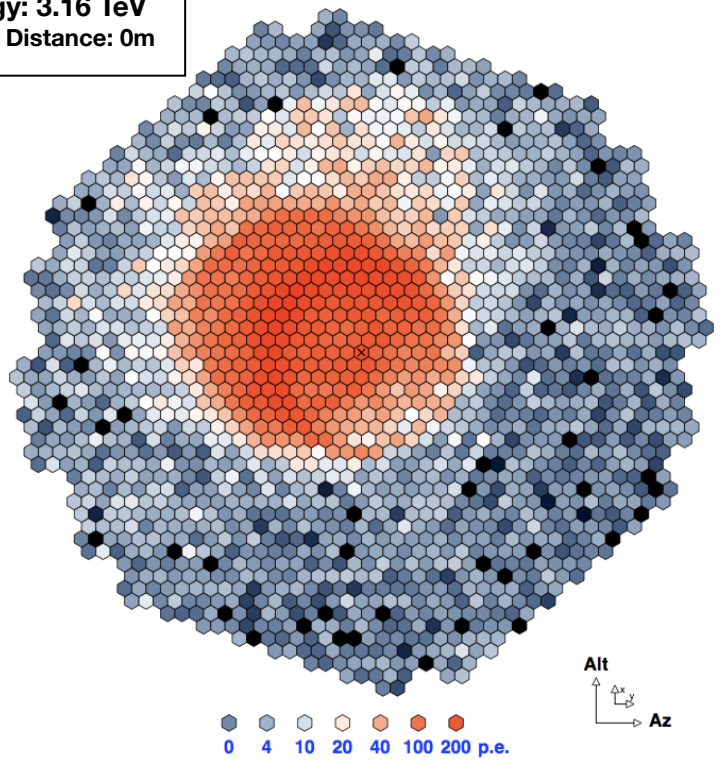


γ-ray Shower
Energy: 1 TeV
Impact Distance: 100m

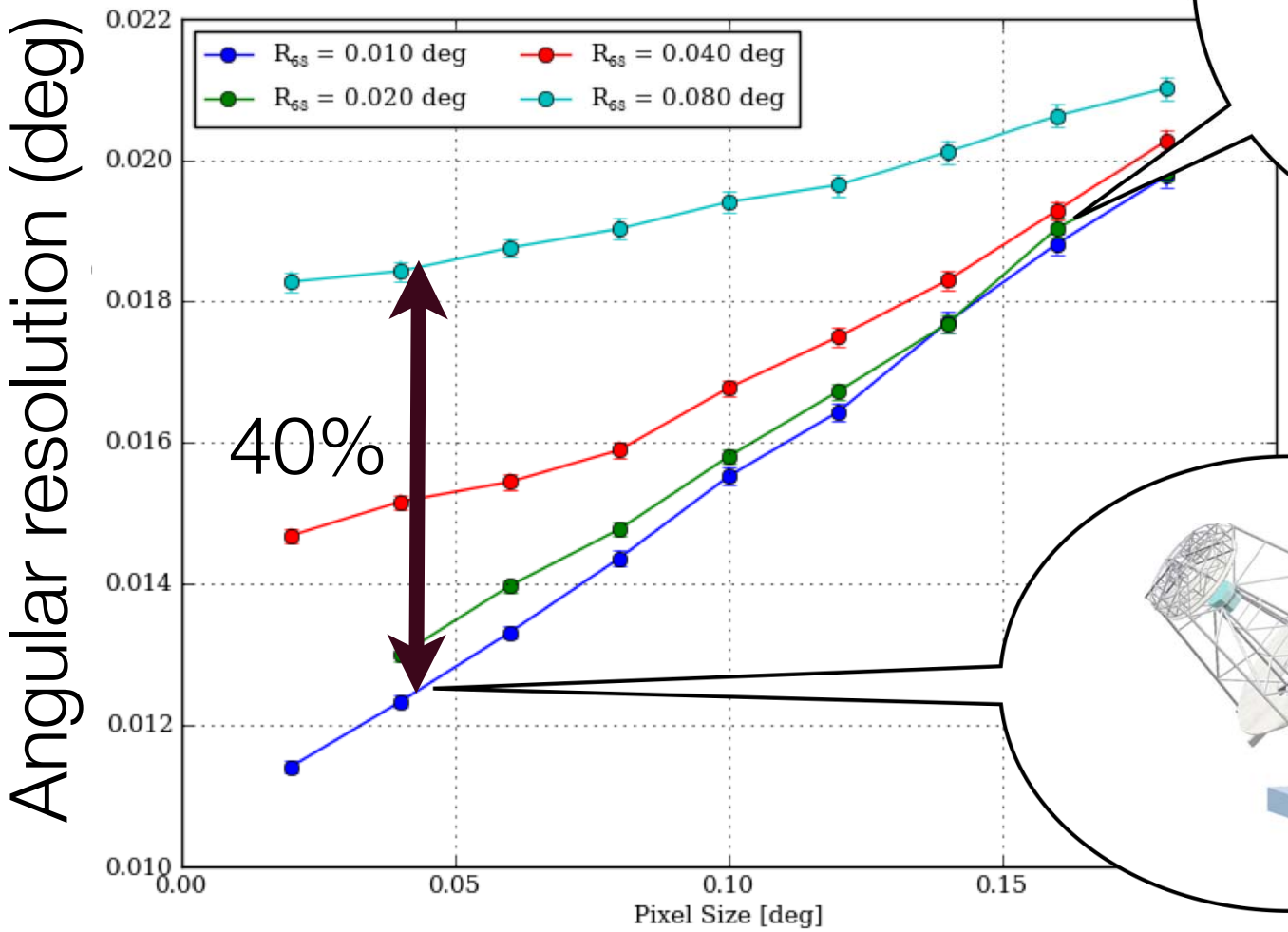
Proton Shower
Energy: 3.16 TeV
Impact Distance: 0m

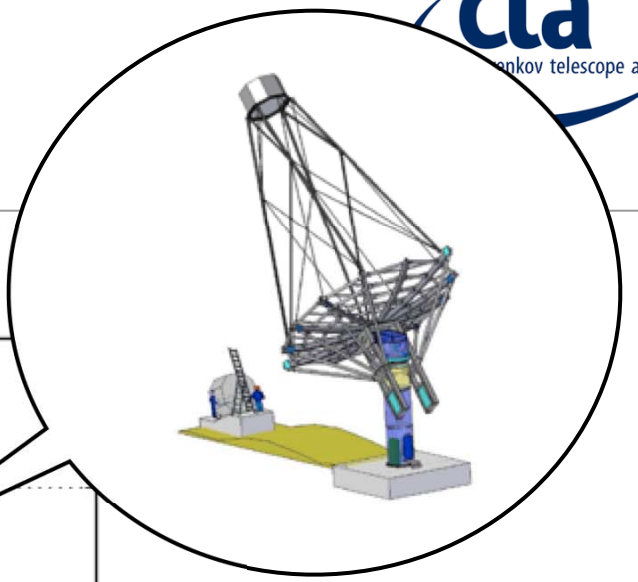


Single Mirror Telescope

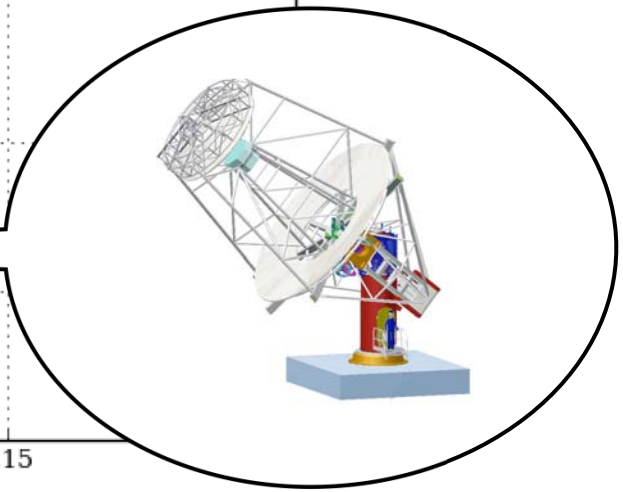


Performance enhancement



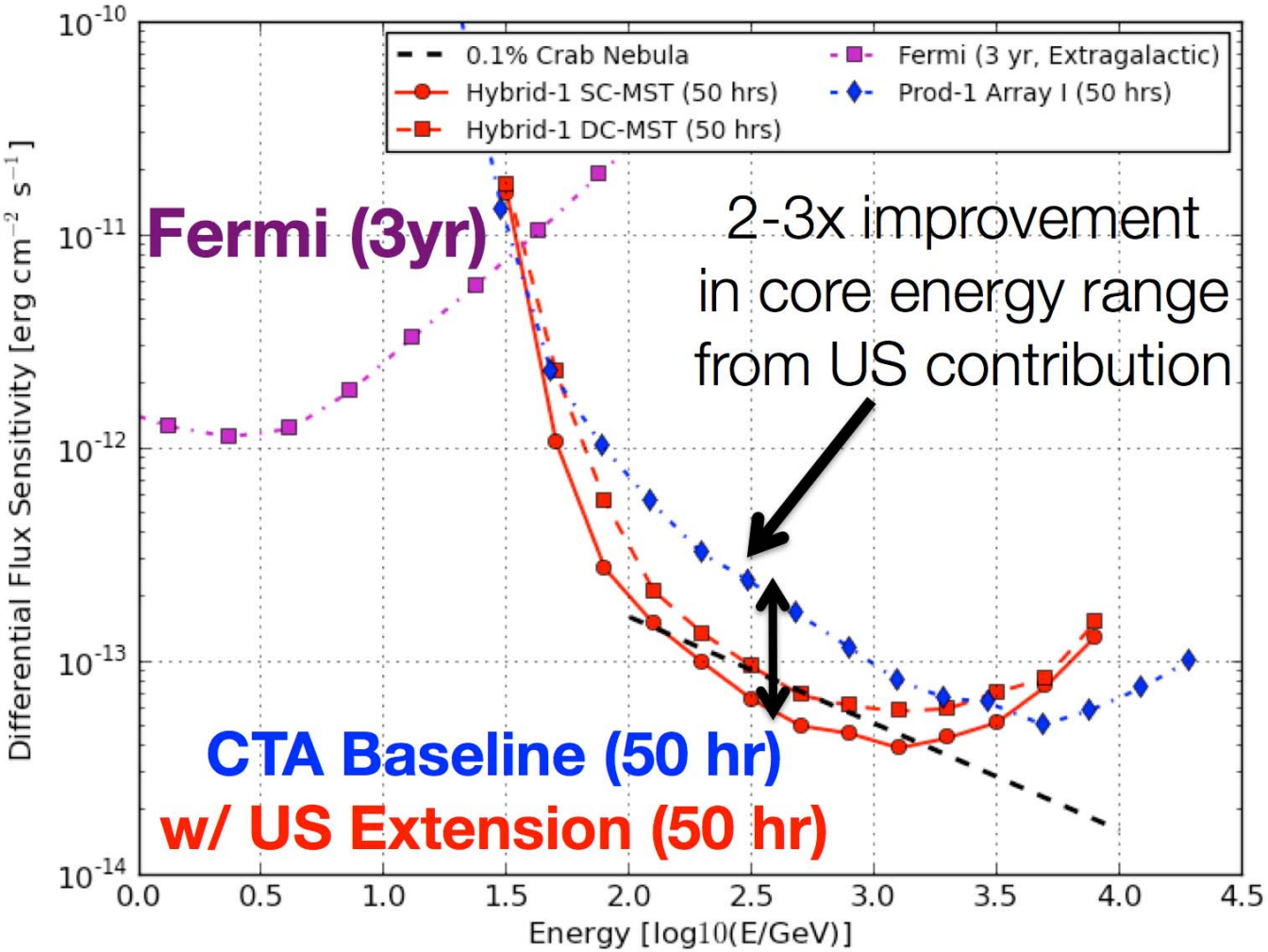


12m Single Mirror telescope



9.5m Dual Mirror telescope

Results in enhanced sensitivity

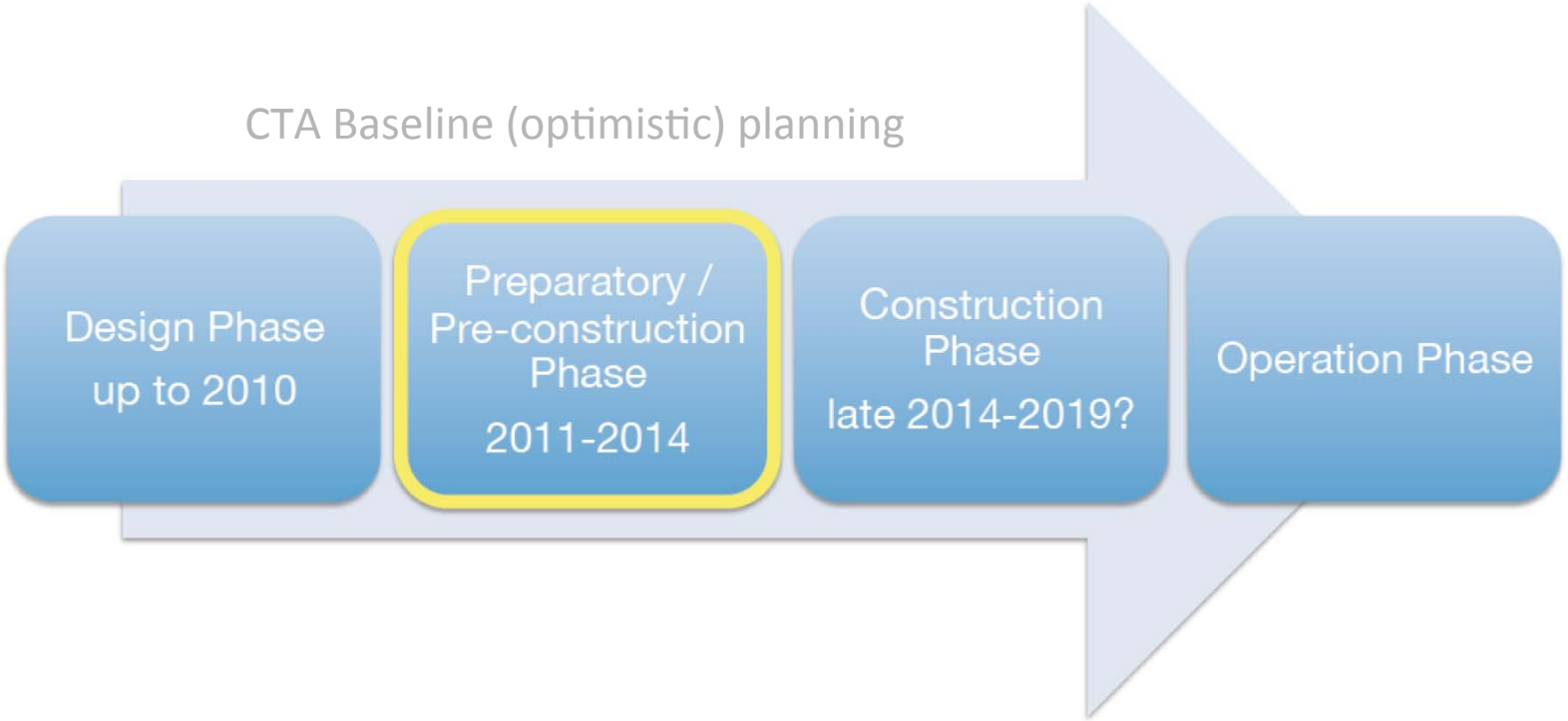


CTA Baseline (Prod-1): See K. Bernlohr et al. 2012, arXiv:1210.3503
w/ US Extension (Hybrid-1): See T. Jogler et al. 2012, arXiv: 1211.3181

NSF-MRI funding for prototype telescope

- Construct a prototype dual-mirror telescope (2012-2015)
  - Project Total Budget: $4.88M
  - NSF contribution: $3.64M
  - Cost sharing (13 US Universities & 2 National Labs): $1.24M
- Main goals:
  - Detailed cost and performance demonstration
- The first practical step in the US towards CTA

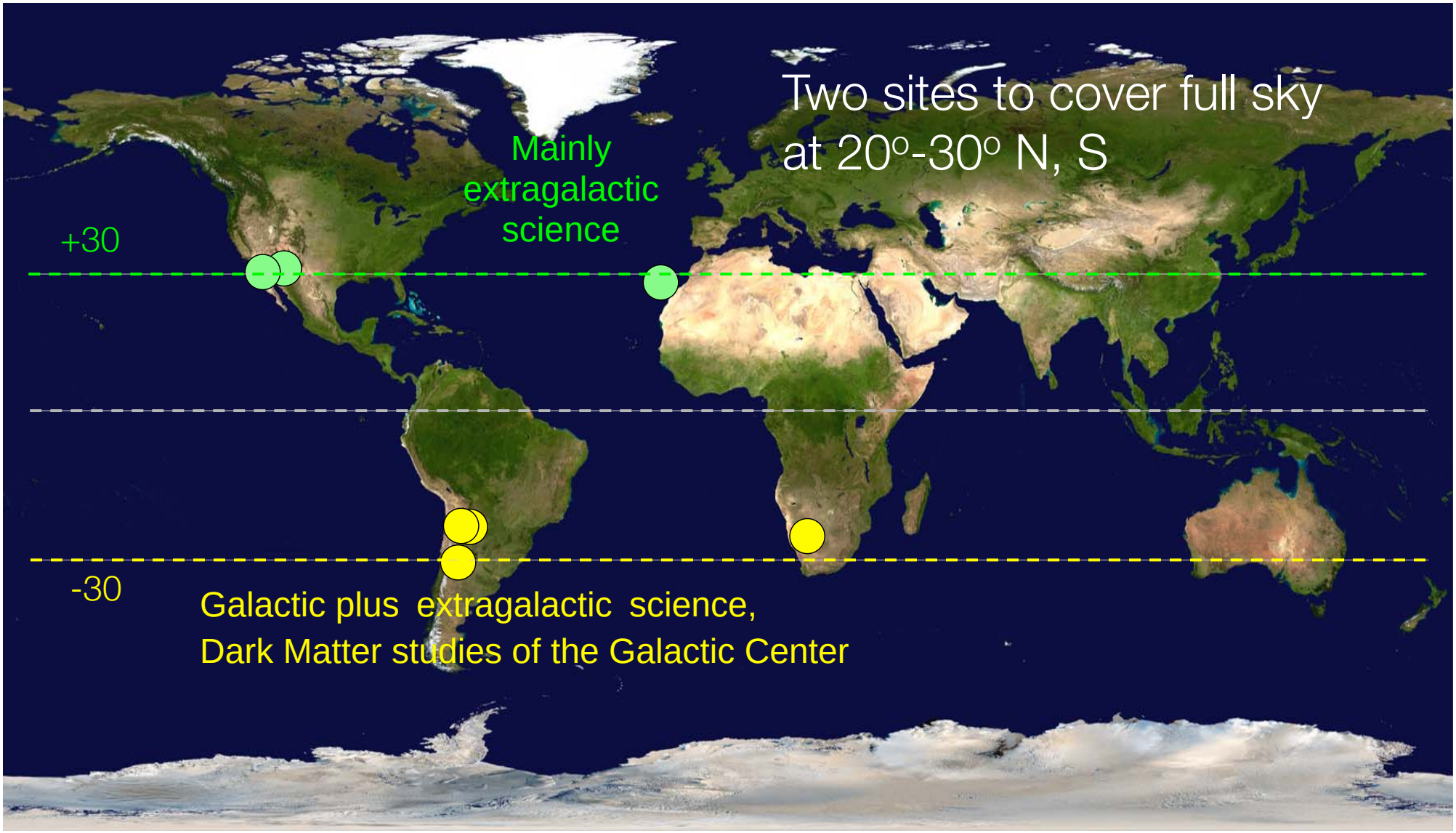
Timelines



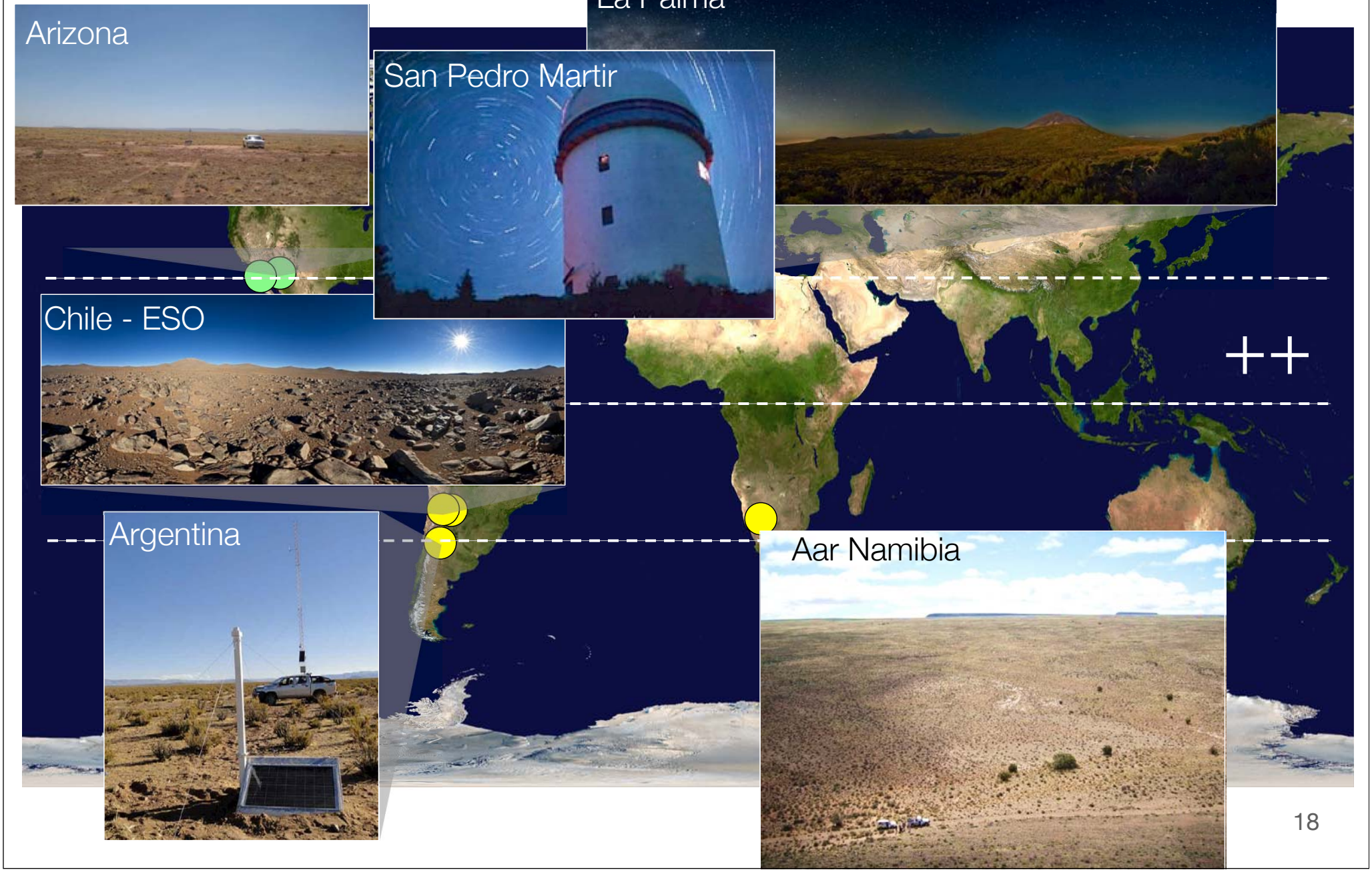
NSF MRI and CTA-US timeline

2012-2013	SCT prototype design
2013-2014	SCT prototype construction
2014-2015	SCT prototype commissioning & operation
2016	CTA-US “CTA Extension” construction proposal

Sites: Candidates



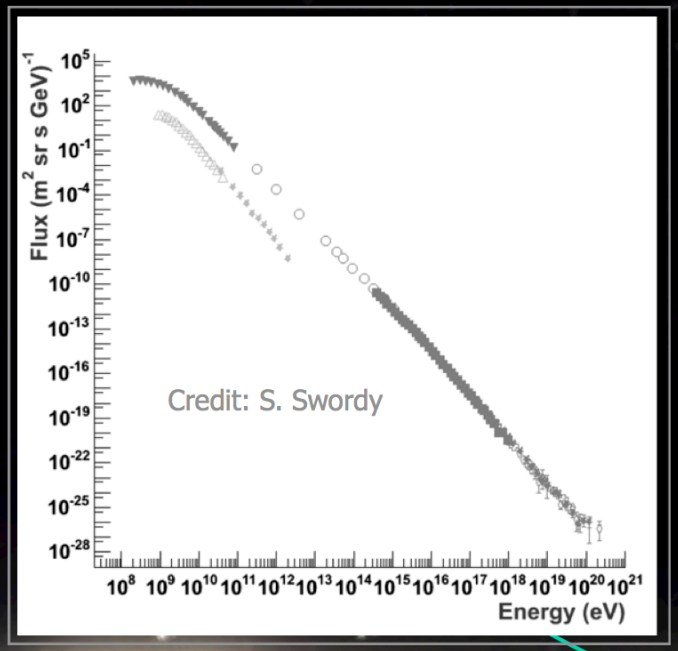
Sites: Candidates



Sites: Candidates

- Several good sites to chose from
  - Extensive studies ongoing
- Decisions late 2013
  - Selection will take into account weather, construction / operations costs, performance (from simulations), risks, ...
- Site development 2014+
- First telescopes operating on site in 2016

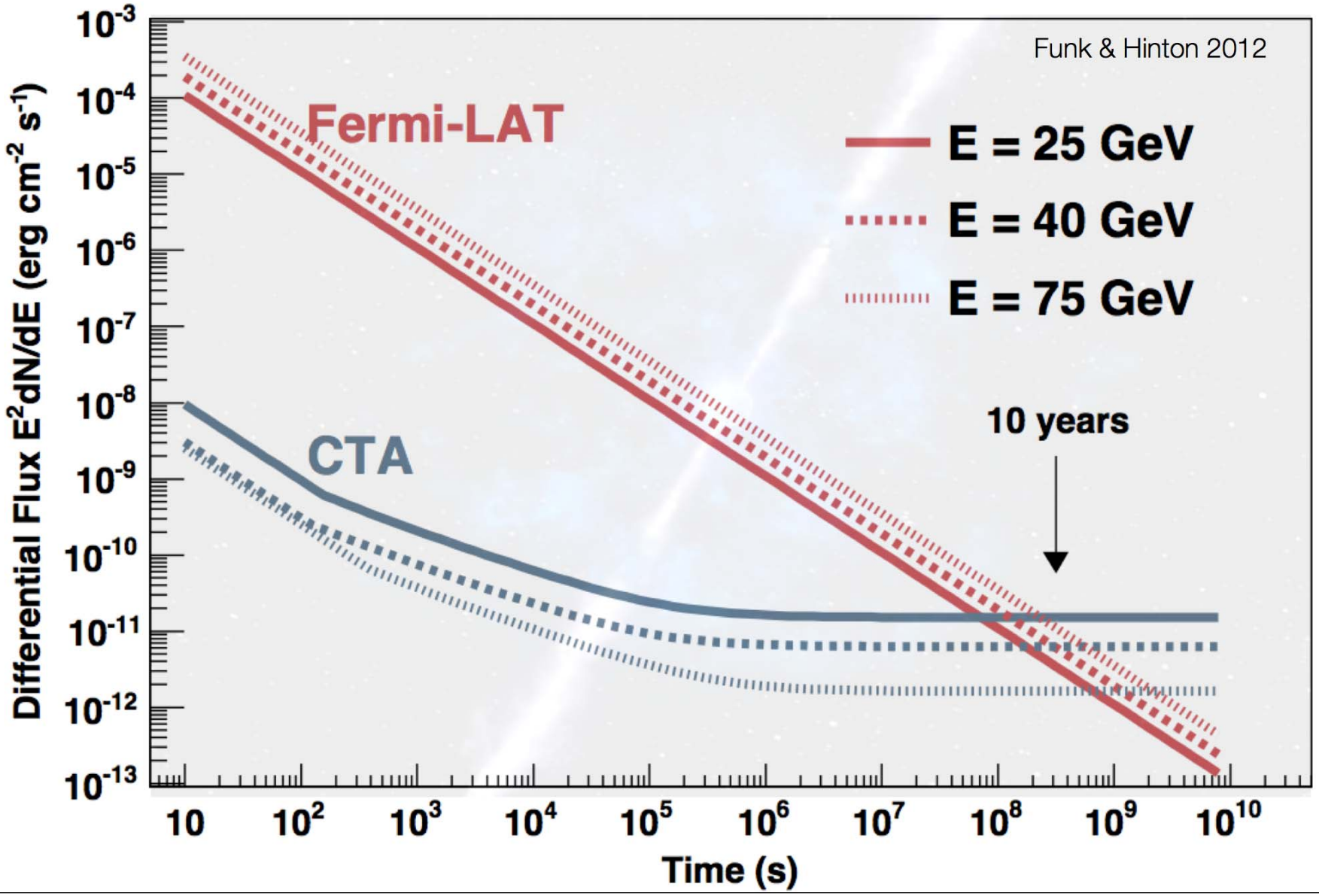
Guaranteed high-energy astrophysics



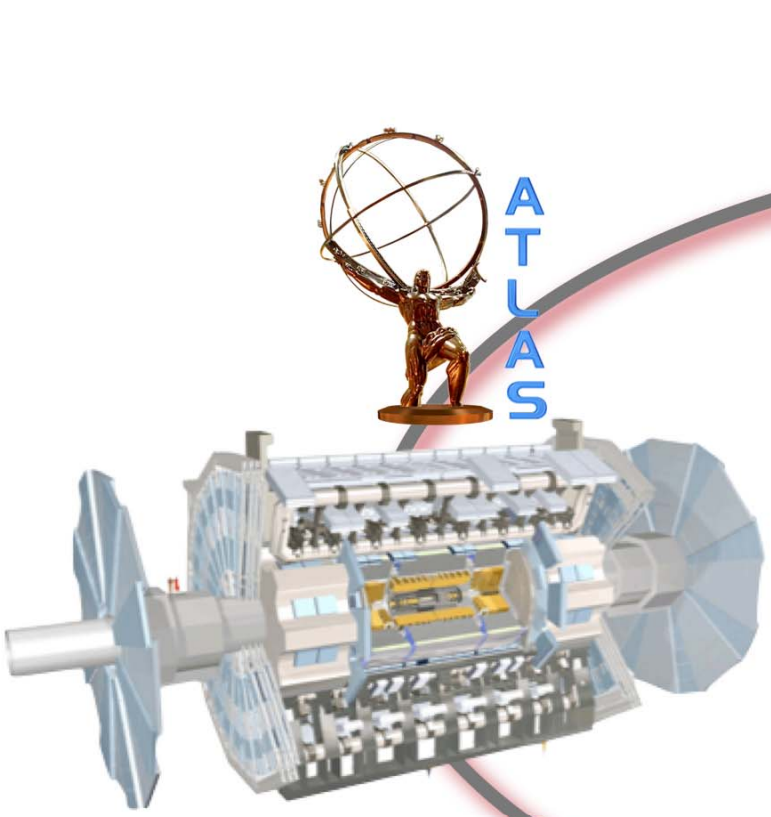
γ rays (and neutrinos)

Cosmic ray protons (and electrons)

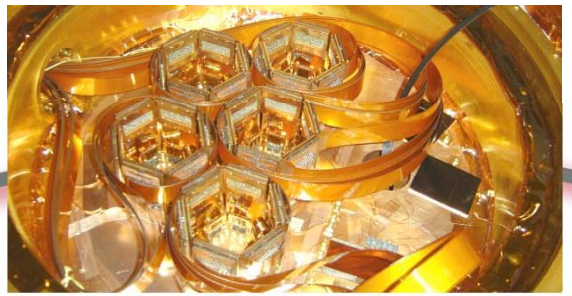
Opening up the Transient domain

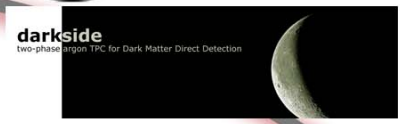


Particle Dark Matter

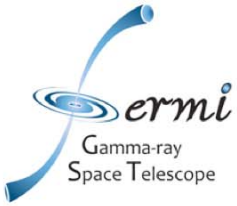


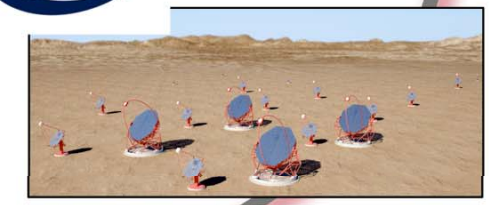
Colliders





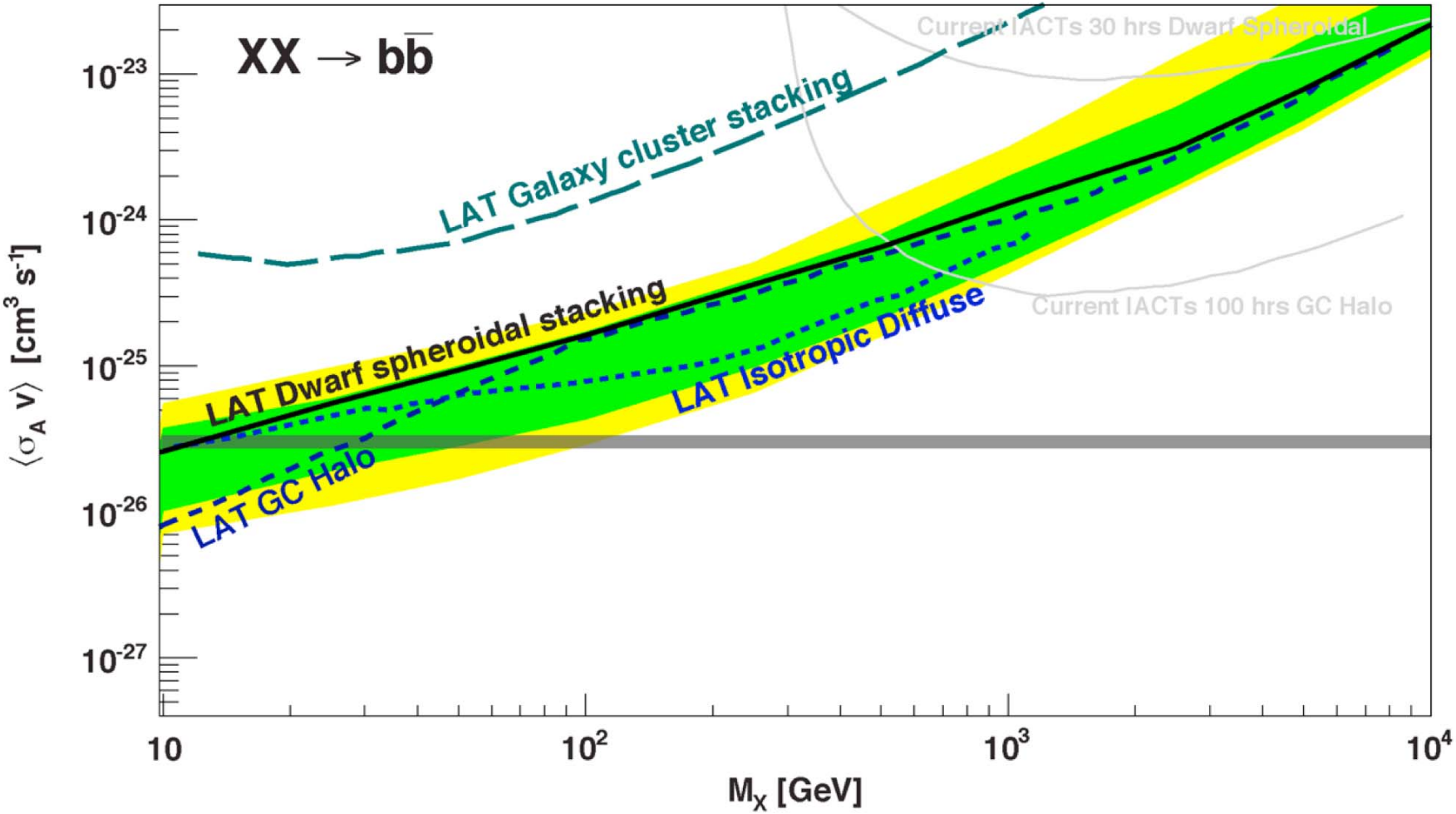
Direct Detection



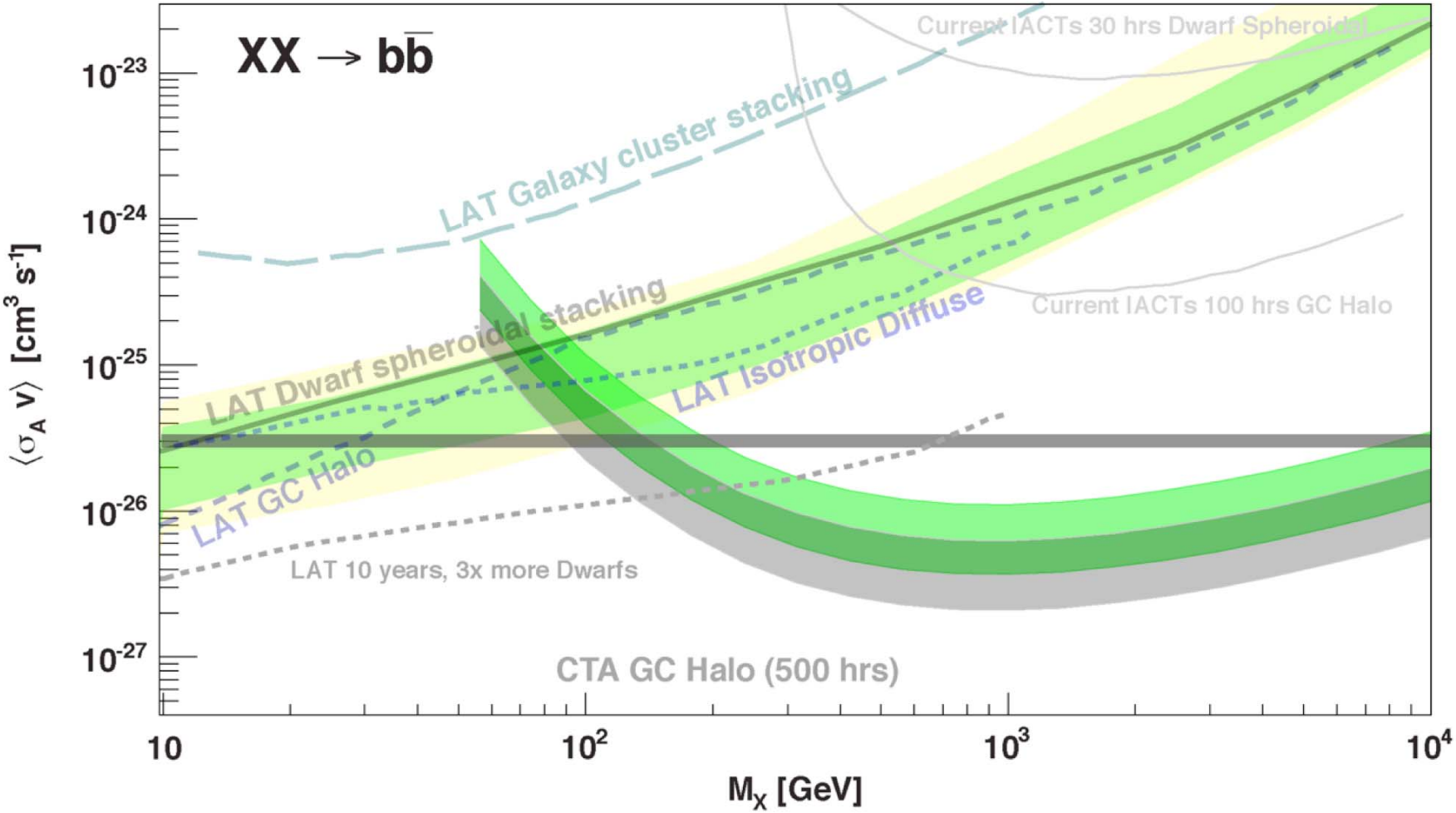


Indirect Detection

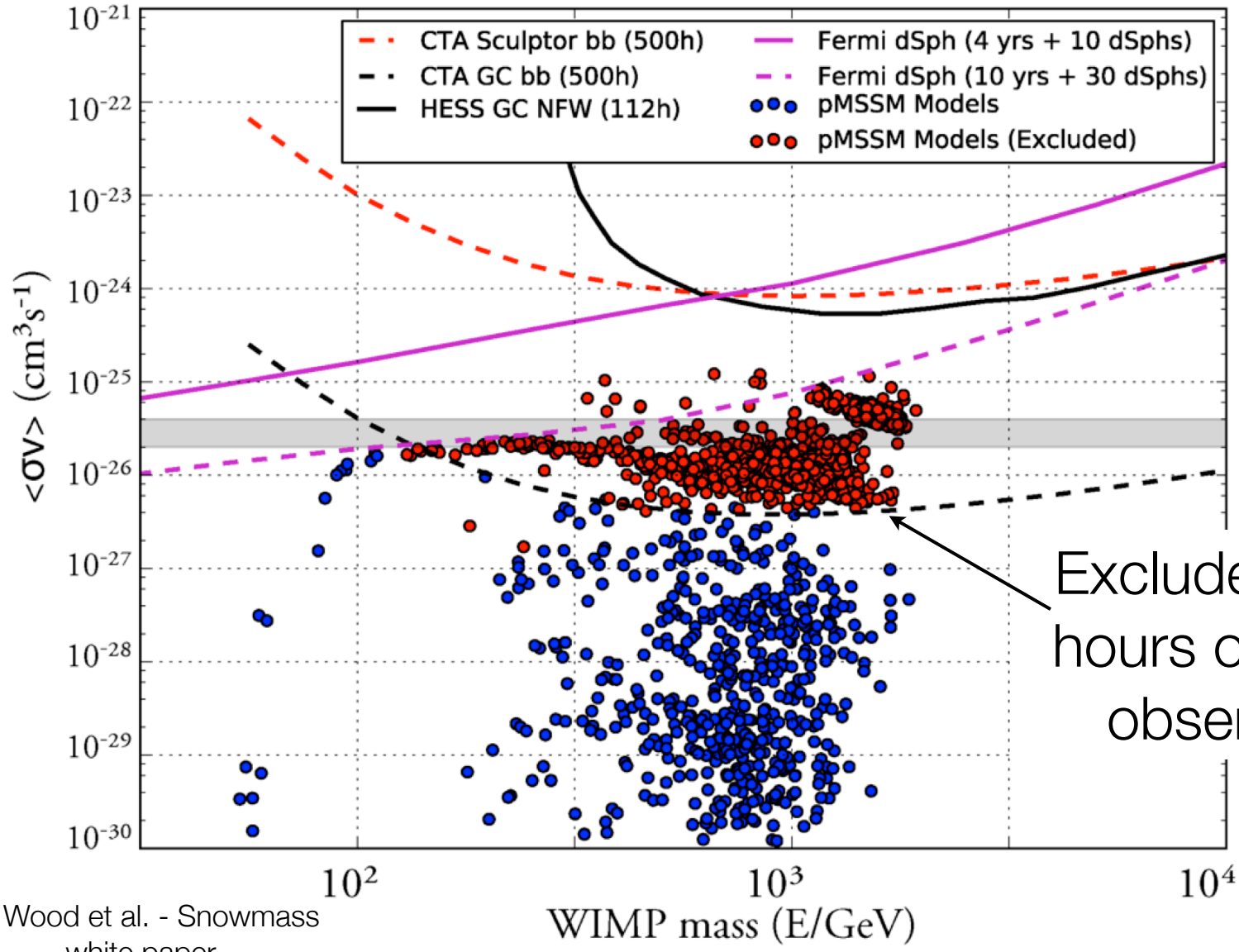
CTA covers the high-mass WIMP space



CTA covers the high-mass WIMP space



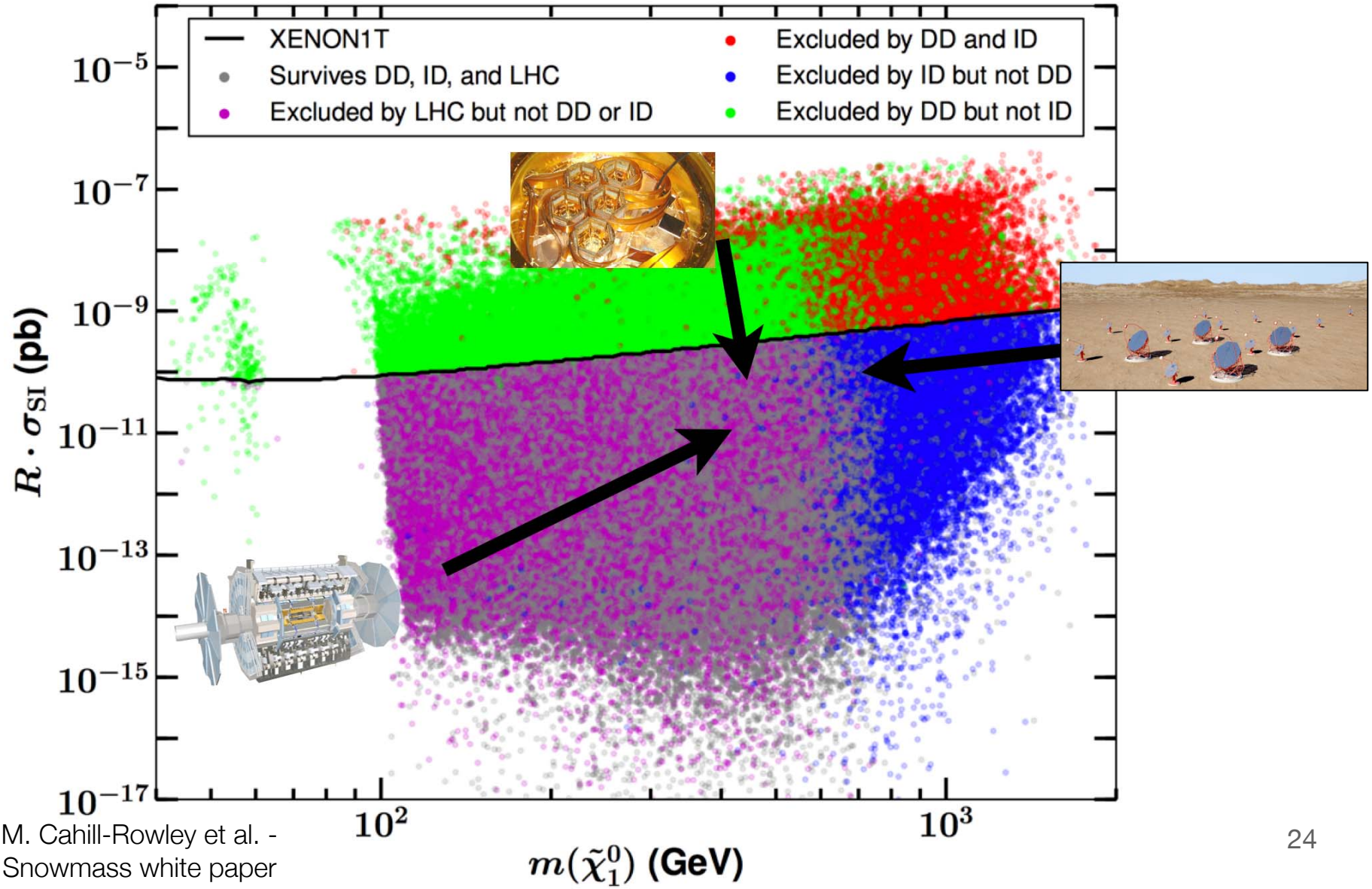
Vanilla dark matter WIMPs covered by ~2020



Excluded by 500 hours of GC halo observations

M. Wood et al. - Snowmass white paper

Complementarity -SUSY scan (pMSSM)



M. Cahill-Rowley et al. - Snowmass white paper

A Possible Timeline

2013

YOU ARE HERE

2014

LUX sees
elastic scat
consistent
mass <

2015

Xenc
a simil

2016

2017

A positive signal of axion conversion is observed at an upgraded ADMX.

2018

2020

	Mass: 150 +/- 0.1 GeV	Mass: 20 μeV
	Spin: > 0	Spin: 0
	Stable?	Stable?
Couplings:		Couplings:
	Gravity	Gravity
	Weak Interaction?	Weak Interaction
	Higgs?	Higgs?
	Quarks / Gluons	Quarks / Gluons?
	Leptons	Leptons?
	Thermal Relic	Thermal Relic?

A multi-pronged search strategy identifies a mixture of dark matter which is 50% classic WIMP and 50% axion.

Fermi observes a faint gamma ray line at 150 GeV from the galactic center.

Neutrinos are seen coming from the Sun by IceCube.

Observation at a Higgs factory indicates that the interaction with leptons is too strong to saturate the relic density.

Measure dark matter density profile of our Galaxy with CTA

Modified T. Tait's plenary talk

Summary

- A brilliantly successful and still immensely promising field invented and developed in the US (Whipple, VERITAS, Fermi-LAT) starts to be led outside the US for the next-generation instruments
  - US can make a significant impact in Dark matter studies with CTA. In numbers: factor 4-9 reduction in observation time on any target through addition of US telescopes
- Ultimate dream: measure the WIMP distribution in our Galaxy and in the Universe